



IIT ROORKEE



NPTEL ONLINE
CERTIFICATION COURSE

WASTE TO ENERGY CONVERSION

DENSIFICATION OF SOLIDS-1

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What is densification ?

Densification: Densification is the process of increasing the density of something. It makes a fuel denser and gives more uniform properties with respect to its raw form.

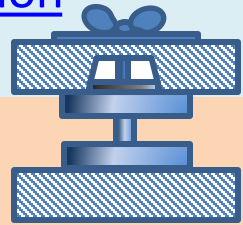
Advantages:

- Simplified mechanical handling and feeding
- Uniform combustion in boilers
- Reduced dust production
- Reduced possibility of spontaneous combustion in storage
- Simplified storage and handling infrastructure, lowering capital requirements at the combustion plant
- Reduced cost of transportation due to increased energy density

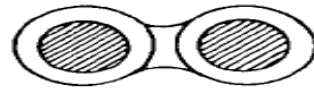
Disadvantages:

- The major disadvantage to biomass densification technologies is the high cost associated with some of the densification processes.

Steps: compaction, compression, concretion, concentration -
increase in density



- The densification of biomass under high pressure results in mechanical interlocking and increased adhesion/cohesion (molecular forces like van der Waal's forces) of the solid particles, which form intermolecular bonds in the contact area.



Hardening binders



Molecular forces

Highly **viscous binders** (**Van der Waal's forces**)
Adsorption layers



Form -closed bonds
(Interlocking)



Electrostatic
forces

Binding Mechanism

Source: **Biomass briquetting: technology and practices**, P.D. Grover & S.K. Mishra, Food and agriculture organization of the united nations Bangkok, April 1996

- When the material is compacted with low to moderate pressure (0.2-5 MPa), then the space between particles is reduced.
- If pressure is increased at a certain stage particular to each material, the cell walls of the cellulose constituent are collapsed.
- The pressures required to achieve such high densities are typically 100 MPa plus.
- A binding agent is necessary to prevent the compressed material from springing back and eventually returning to its original form.

- Additives of high viscous bonding media (binders), such as tar, molasses and other molecular weight organic liquid can form bonds very similar to solid bridges.
- Adhesive forces at the solid/liquid interface and cohesion forces within the solid are used for binding.
- The binding agent can either be added to the process or, when compressing ligneous material, be part of the material itself in the form of lignin.

The resulting solid is called a briquette if, roughly, it has a diameter greater than 30 mm. Smaller sizes are normally termed pellets though the distinction is arbitrary.

Briquettes



Source: [http://www.iosrjen.org/Papers/vol3_issue1%20\(part-4\)/H03143642.pdf](http://www.iosrjen.org/Papers/vol3_issue1%20(part-4)/H03143642.pdf)

Pellets



Source : <http://agrofuelindia.com/>

- The physical properties (moisture content, bulk density, void volume and thermal properties) of the biomass are the most important factors in the binding process of biomass densification.
- The ultimate density of a briquette will depend to some extent on a range of factors including, most importantly, the nature of the original material and the machine used and its operating condition as well as other minor factors.

Types of briquetting

Based on compaction, the briquetting technologies can be divided into:

- ***High pressure compaction***
- ***Medium pressure compaction with a heating device***
- ***Low pressure compaction with a binder***

Rage of pressures

Low Pr. : up to 5 MPa

Intermediate Pr.: 5-100 MPa

High Pr.: 100 MPa

- Usually high pressure processes releases sufficient lignin to agglomerate the briquette though this may not be true for all materials.
- Intermediate pressure machines may or may not require binders, depending upon the material.
- Low-pressure machines invariably require binders.



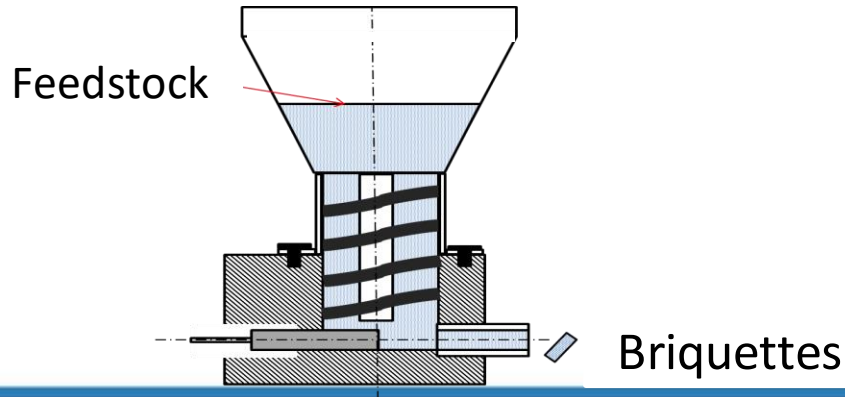
Important Briquetting Process

- High and medium pressure operation
- High and medium pressure compaction normally does not use any additional binder.
- Normally, the briquetting process bases either on piston press or screw press technology.
- Other briquetting technologies are less applicable in developing countries because of high investment costs and large throughputs, e.g. roller-presses and pellet mill to produce pellets or briquettes.

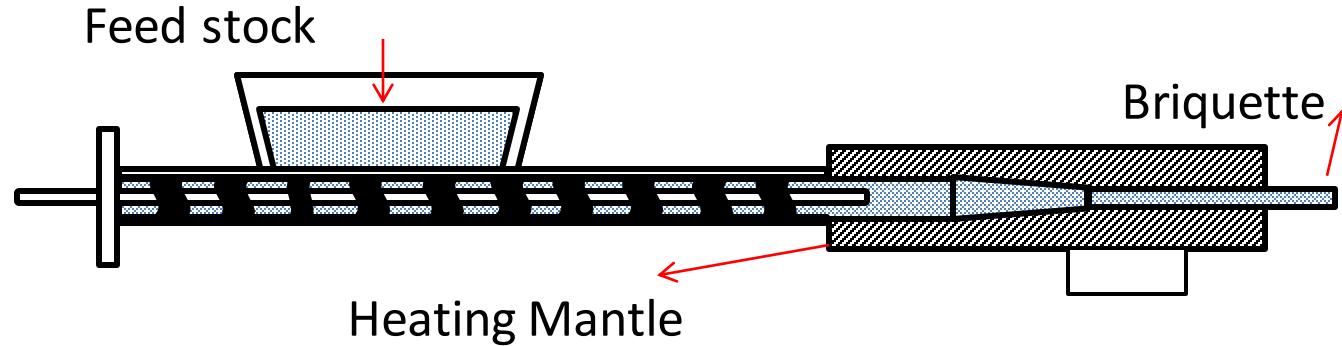


Piston presses

- Piston presses punch the feed material into a die with very high pressure, either mechanically by a reciprocating ram powered by a massive flywheel, or by a hydraulically driven piston.
- The mass is compressed and forms a very dense briquette.



Simplified sketch of piston press technology



- In a screw press/ screw extruder, the rotating screw takes the material from the feed port, through the barrel, and compacts it against a die which assists the build-up of a pressure gradient along the screw.
- It consists three distinct zones: feed, transport and extrusion zones.

Performance of the process (speed of densification, the energy consumption and the quality of the briquettes) depend on:

- flow ability and cohesion of the feed material
 - particle size and distribution
 - surface forces
 - adhesiveness
- Screw presses produce high quality briquettes with a homogenous structure and good combustibility
 - Require only little maintenance.
- The main disadvantage is that the wear of the screw leads to elevated spare part costs.

Important Briquetting Process

Low pressure operation

- This process requires a binding agent to assist the formation of bonds between the biomass particles.
- Two types of binding agents (organic and inorganic) are normally used
- The most important binders are:
 - **Organic binders**
 - Bitumen
 - Molasses
 - Starch
 - Coal tar
 - Resin
 - **Inorganic binders**
 - Cement
 - Lime
 - Clay
 - Sulphite liquor
- During the compaction process the briquettes are brought into shape without giving them substantial strength.
- After a subsequent curing step (drying, burning, chemical reaction, etc.) the “green” briquettes are developed with the required strength and stability.



Comparison of different densification Processes

Parameter	Densification Technology			
	Screw press	Piston Press	Roller press	Pellet mill
Optimum moisture content of the raw material (%)	4 - 8	10 – 15	10 – 15	10 – 15
Particle size (mm)	2 - 6	6 - 12	< 4	< 3
Wear of contact parts	High	Low	High	High
Output from machine	Continuous	In strokes	Continuous	Continuous
Specific energy consumption (kWh/t)	37 – 150	37 – 77	30 – 83	16 – 75
Through puts (ton/hr)	0.5	2.5	5 – 10	5
Unit density (g/cm ³)	1.0 – 1.4	2.5	0.4 – 0.6	1.1 – 1.2
Bulk density (g/cm ³)	0.5 – 0.6	< 0.1	-	0.7 – 0.8
Maintenance	Low	High	Low	Low
Combustion performance of briquettes	Very good	Moderate	Moderate	Very good

Source: A review of biomass densification systems to develop uniform feedstock commodities for bioenergy application
, J.S.Tumuluru, Biofuels ,Bio products,Bio refining,2011



Carbonization process

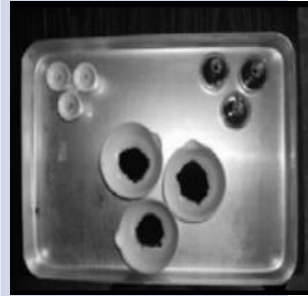
- Although briquettes can be used directly as a fuel, the burning of briquettes have some demerits as follows:
 - Increased generation of smoke
 - Reduced ignition and burning properties
 - Low heat value
 - Not stable under wet condition
- Carbonization is partial pyrolysis process (heated upto 600 °C) and burnable gases like CO, CH₄, H₂, formaldehyde, methanol, formic and acetic acid as well as nonburnable gases like CO₂ and H₂O and liquid tar are released.
- Due to above reason carbonized briquettes overcomes all the above demerits



Carbonization process

- The off-gas of the process is of high energetic value and can be used to balance the energy and heat demand of the carbonisation.
- Carbonised briquettes can be produced from agricultural residues through two possible production sequences:
 - Carbonization → grinding → briquetting
 - Grinding → briquetting → carbonization.

Change of properties due to carbonization

Characteristics	Pine Needle	Pine Needle char	PNB
Mean Moisture content(%)	9.76	7.500	6.89
Mean Ash content(%)	4.37	5.390	11.21
Mean Volatile Matter Content(%)	70.03	17.960	29.04
Fixed Carbon Content(%)	15.83	69.150	52.85
Picture showing the Proximate Analysis Sampling			
Source: Pine Needle Briquettes: A Renewable Source of Energy , Sudip Pandey, Rabindra Prasad Dhakal, International Journal of Energy Science , 2013			

Thanks...

